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PEDOT-7764; No. of Pages 7
ARTICLE IN PRESS
International Journal of Pediatric Otorhinolaryngology xxx (2015) xxx–xxx
Contents lists available at ScienceDirect
International Journal of Pediatric Otorhinolaryngology
journal homepage: www.elsevier.com/locate/ijporl



# Auditory interference control in children with learning disability: An exploratory study

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ARTICLE INFO

*Article history:*
Received 11 June 2015
Received in revised form 12 September 2015
Accepted 14 September 2015
Available online xxx

*Keywords:*
Auditory Stroop
Auditory processing disorder
Interference control
Learning disability

ABSTRACT

*Objectives:* The current study aimed to compare the auditory interference control of participants with Learning Disability (LD) to a control group on two versions of an auditory Stroop task.
*Methods:* A group of eight children with LD (clinical group) and another group of eight typically developing children (control group) served as participants. All the participants were involved in a semantic and a gender identification-based auditory Stroop task. Each participant was presented with eight different words (10 times) that were pre-recorded by a male and a female speaker. The semantic task required the participants to ignore the speaker's gender and attend to the meaning of the word, and vice-versa for the gender identification task. The participants' performance accuracy and reaction time (RT) was measured on both the tasks.
*Results:* Control group participants significantly outperformed the clinical group participants on both the tasks with regard to performance accuracy as well as RT.
*Conclusion:* The results suggest that children with LD have problems in suppressing irrelevant auditory stimuli and focusing on the relevant auditory stimuli. This can be attributed to the auditory processing problems in these children.



## 1. Introduction

In our everyday environment, we are exposed to multiple sources of information that compete for our attention. In most instances the human brain suppresses the irrelevant stimuli and processes the relevant stimuli. An example to illustrate this phenomenon is Stroop effect, in which an individual is able to attend to a certain dimension of a stimulus, while ignoring the other dimension. The delay in reaction time (RT) in attending to the target stimulus in the presence of a conflicting stimulus is termed as Stroop effect [1]. The Stroop effect has been extensively applied to investigate cognitive abilities over the past 70 years [2–5].

In case of visual Stroop effect, naming the color of a word takes longer time and is more prone to errors when the name of the color (e.g., blue, green, or red) is printed in a color not denoted by the name (incongruent) (e.g., the word "red" printed in blue ink instead of red ink), than when the color of the ink matches the name of the color (congruent). Congruency refers to the compatibility of a verbal label to the relevant physical attribute of the stimuli. Incongruency refers to the incompatibility that exists between the verbal label and relevant physical attribute of the stimulus [1].

Over the past few years, there have been numerous variations of the classic visual Stroop task. One such variation is the auditory Stroop task [6,7]. Auditory Stroop effect reveals an individual's ability to control the interfering auditory stimuli, and selectively attend to the relevant auditory stimuli. Past studies have either used linguistic stimuli or non-linguistic stimuli to elicit auditory Stroop effect to investigate interference control in healthy individuals [8–10]. For example, Henkin et al. measured auditory Stroop effect in 16 individuals using a word meaning task and a gender identification task [8]. To elicit the auditory Stroop effect, the participants were required to identify the meaning of the presented words while ignoring the gender of the speaker's voice, and vice-versa. The results indicated that incongruent condition elicited a significant auditory Stroop effect characterized by prolonged RT, and reduced performance accuracy. There have also been attempts to investigate the auditory Stroop effect across age [11–13], and gender [7,14–16].

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http://dx.doi.org/10.1016/j.ijporl.2015.09.017
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Interference control using auditory Stroop tasks has not been investigated in clinical population to the extent it has been investigated in healthy individuals [15,17]. A handful of studies have investigated interference control using auditory Stroop tasks in individuals with hearing impairment (HI) [18], learning disability (LD) [19], and attention deficit hyperactivity disorder (ADHD) [20,21].

Jerger et al. subjected 20 children with HI and 60 normal hearing children to an auditory Stroop task, which required them to selectively attend to the voice-gender of speech targets while ignoring the sematic content [18]. The results revealed that children with HI showed minimal Stroop interference in comparison to the normal hearing children. Van Mourik et al. compared the interference control of children with ADHD to a control group on visual and auditory Stroop tasks [21]. It was found that children with ADHD demonstrated similar performance as the control group with regard to interference control. Kumar et al. compared selective attention in typically developing children to children with LD using an auditory Stroop task [19]. The researchers employed a word meaning/laterality auditory Stroop task, where the words "left" and "right" were randomly presented to one of the ears of the participants. The participants were required to depress the "L" button on the keyboard if the word was heard in the left ear, and similarly depress the "R" button if the word was heard in the right ear. Children with LD exhibited poorer selective attention (interference control) manifested by increased RT and reduced performance accuracy for the auditory Stroop task.

The findings of the above studies suggest that children with LD exhibit deficits in auditory interference control by taking longer time to respond to incongruent stimuli compared to children with ADHD and HI. This finding in children with LD is not surprising as children with LD are known to present with auditory processing difficulties [22]. Investigating auditory interference control in children with LD could reveal how these children perceive spoken language in real world environment. This information in turn could have implications for designing effective intervention strategies. To our knowledge, as there has been limited research to measure auditory interference control in children with LD using a Stroop task, it is important to examine the reliability of the findings in a similar cohort of individuals with LD. This was the first aspect that was examined in this study.

Findings from previous studies suggest that the amount of interference levels differ among the auditory Stroop tasks based on the type of incongruent stimuli presented [15,23]. In the study by Kumar et al. participants were required to just focus on laterality, and ignore the semantic content of the words [19]. If the participants in the study were instructed to focus on the semantic content of the presented words, rather than laterality, it is likely that the results of the Stroop task would have been different. Hence, it is necessary to examine the auditory interference control in individuals with LD as a function of auditory Stroop task. This was the second aspect examined in the current study.

Taking the above two aspects into consideration, the objectives of the current study were to measure RT and performance accuracy in participants with LD and a control group on two different versions of an auditory Stroop task (gender identification task and semantic task). The current study attempted to answer the following research questions:

(1) Is there a difference between participants with LD and control group participants in performance accuracy on semantic and gender identification-based auditory Stroop tasks?
(2) Is there a difference between participants with LD and control group participants in RT on semantic and gender identification-based auditory Stroop tasks?
(3) Is there an influence of the nature of the auditory Stroop task on the performance accuracy and RT among both the groups of participants?

## 2. Methods

### 2.1. Participants

#### 2.1.1. Clinical group

The clinical group comprised eight participants (5 males & 3 females) in the age range of 12–15 years ($M$ = 13.3, SD = 1.13), who were recruited based on a non-probability convenience sampling from a school that provided inclusive education. The clinical group participants were diagnosed to have LD since one year at the time of recruitment by the school clinical psychologist. The clinical group participants were raised in a middle socio-economic status. In the context of the current study, the term "learning disability" referred to a heterogeneous group of disorders characterized by difficulty in acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities due to central nervous dysfunction, and without other co-morbid conditions [24]. As LD is a heterogeneous group of disorders, the specific type of learning disability for each participant was determined based on the performance on:

(1) a psycho-educational assessment battery. This included administration of National Institute of Mental and Neurosciences (NIMHANS) Index for Specific Learning Disability (NIS), Malin's Intelligence Scale for Indian Children (MISIC), and Binet-Kamat Test of Intelligence (BKT), and
(2) a comprehensive contextual assessment.

Detailed interviews were also conducted with participants as well as with their parents to gather additional information.

The assessment protocol was based on the practice guidelines for diagnosis of learning disability proposed by the Indian Association of Clinical Psychologists [25]. As all the participants were enrolled in a school where the medium of instruction was English, the assessment was carried out in English. The assessment was conducted by a clinical psychologist and a learning disability co-ordinator at the school where participants were recruited. The details of the assessment protocol are described below.

##### 2.1.1.1. Psycho-educational battery.

- NIS: This is a standardized assessment tool developed by Kapur et al. [26]. It includes an attention test (number cancellation task), language test (for assessing reading, writing, spelling and comprehension), arithmetic test (that assesses addition, subtraction, multiplication, division and fractions), visuomotor integration test, and an auditory memory test. If there was a two-year discrepancy between the participant's potential and his/her performance in any one or more of the four areas (i.e. (e.g., reading, writing, language, mathematics), that earned him/her a diagnosis of SLD as per ICD-10.
- MISIC: This assessment tool is an Indian version of Wechsler Intelligence Scale for Children developed by Malin [27]. It is designed to assess aspects such as comprehension, arithmetic abilities, vocabulary, digit span, picture completion, picture arrangement, block design, assembly, and coding. Norms are provided for children aged 5–15 years. MISIC is a very popular tool that has been widely used in India to assess intelligence.
- BKT: This is an Indian adaptation of the Stanford–Binet test of intelligence [28]. It includes both verbal as well as performance tests, and can be used for individuals aged 3–22 years.



Please cite this article in press as: R.M. Thomas, et al., Auditory interference control in children with learning disability: An exploratory study, Int. J. Pediatr. Otorhinolaryngol. (2015), http://dx.doi.org/10.1016/j.ijporl.2015.09.017

Five of the eight participants were administered all the three tests. Three participants were administered only NIS and BKT, these three participants were not administered MISIC for unknown reasons. The overall intelligence quotient of the clinical group participants ranged from 88 to 95, ruling out intellectual impairment.

*2.1.1.2. Contextual assessment.* Contextual assessment refers to a series of assessment activities obtained from multiple sources and across different settings that the individual is involved in. Use of contextual assessment allowed the assessors to estimate the exact functioning level of the clinical group participants in each of the four areas of reading, writing, arithmetic, and receptive and spoken language.

- Reading assessment included aspects such as identifying alphabets and sounds of the letters of the alphabet, difficulties associated with reading isolated words including decoding strategies and familiarity in reading homophones, reading comprehension while reading different sentences, and reading fluency.
- Writing assessment included assessing for pencil hold/grip, legibility of letters of the alphabet, spelling errors, mirror writing, use of punctuations, organization of the written content, and mechanics of writing.
- Arithmetic assessment included assessing abilities such as basic mathematical operation (i.e. addition, subtraction, multiplication, and division), maintaining precision during calculations, sequencing multiple steps, interpreting and manipulation of basic geometric configurations, and solving complicated mathematical problems.
- Receptive and spoken language assessment included assessing for phonological awareness (e.g., rhyming, segmentation, phoneme manipulation, blending of isolated sounds and words), sentence construction, vocabulary, usage of plural markers and tense markers, and misarticulations.

The contextual assessment complemented the findings of NIS for each participant. For example, if a participant was diagnosed to have reading disability on NIS, the contextual assessment also revealed that the participant's reading level was not comparable to his/her peers.

*2.1.1.3. Assessment through interviews.*

- Interview with the participants: each of the eight clinical group participants were interviewed regarding their academic abilities. During the interview, care was taken to pose open-ended questions (e.g., elaborate the problems you face when solving mathematical questions) to elicit maximum response from the participants. Each participant spoke at length about their problems in different areas of reading, writing, spelling, and arithmetic.
- Parental interviews: these interviews aimed at eliciting information regarding the participants' developmental, medical, educational, and social history. In addition, reports of previous audiological (pure tone audiometry) and medical examination reports were inspected. The parental reports indicated that all the participants achieved their motor and speech and language milestones appropriately, the participants had not suffered any major medical conditions, and were able to get along very well with their peers. The parents also reported that participants did not have problems with vision and audition. However, the parents reported that all the participants have had problems in academics and did not perform on par with their typically developing peers, and demonstrated problems in attending to classroom instruction. The medical reports also revealed that the participants had uneventful developmental and medical history, and had normal hearing and visual acuity.

The results of the assessment battery revealed that six participants had reading, writing, and arithmetic deficits, one participant had reading and writing deficits, and one participant demonstrated problems in arithmetic alone. None of the participants demonstrated deficits in spoken and receptive language. Details of the tests administered and academic difficulties demonstrated by each of the eight participants are presented in Table 1.

*2.1.2. Control group*

The control group also comprised eight typically developing participants (5 males & 3 females) in the age range of 12–15 years ($M = 13.5$, $SD = 1.3$), matched for age and sex with the clinical group. The control group participants were also recruited based on a non-probability convenience sampling from the same school where the clinical group was recruited. The inclusion criteria for the control group were: (1) no prior history of sensory, motor, or cognitive deficits and (2) no reported history of academic difficulties. All the control group participants were raised in a middle socioeconomic status. Informed consent for participation in the current study was obtained from prospective participants, their parents, and teachers.

*2.2. Stimuli*

Two sets of stimuli were created for the current study. One stimuli set was used for the congruent condition and the second stimuli set was used for the incongruent condition. The stimuli were recorded Kannada (a south Indian language) words /ap̃a/ (father), /añа/(brother), /am̃a/(mother), and /ak̃a/(sister) produced by adult male and female Kannada speakers. The congruent condition elicited four variants of the stimuli, with the male speaker producing the words /ap̃a/ and /añа/ separately, and the female speaker producing each of the female-gender words; /am̃a/ and /ak̃a/. Similarly, the incongruent condition elicited four variants of the stimuli, each of the male-gender words being produced by the female speaker, and the male speaker producing the female-gender words. The main rationale for creating four variants of congruent and incongruent stimuli was to prevent the participants from getting used to a limited set of stimuli. All the eight stimuli were recorded in a sound-treated room using the Praat software [29] at a sampling rate of 44 kHz, and 16-bit quantization level. The duration of each recorded stimulus was 1900 milliseconds (ms).

*2.3. Tasks*

The auditory Stroop effect in both the groups of participants was measured by involving them in a gender identification task and a semantic task. Both these tasks have proven to be successful in eliciting auditory Stroop effect in healthy as well in clinical population [18]. The experiment was conducted at the end of school periods.

*2.3.1. Gender identification task*

During the gender identification task, participants were presented with four variants of congruent stimuli as well as four variants of the incongruent stimuli. The stimuli were presented through high fidelity Tech-Com Digital Sound stereo headphones (SSD-HP 202) at 60 dB SPL. The participants were instructed to ignore the sematic content of the stimulus, and identify the gender of the speaker through a verbal response (i.e. male or female). Each



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**Table 1**
Details of the tests administered and academic difficulties demonstrated by each of the eight participants.

| Participant | Tests administered | Reading | Writing | Arithmetic | Spoken and receptive language |
|---|---|---|---|---|---|
| 1 | NIS, MISIC, & BKT | + | + | + | – |
| 2 | NIS, MISIC, & BKT | + | + | – | – |
| 3 | NIS & BKT | + | + | + | – |
| 4 | NIS & BKT | + | + | + | – |
| 5 | NIS, MISIC, & BKT | – | – | + | – |
| 6 | NIS, MISIC, & BKT | + | + | + | – |
| 7 | NIS & BKT | + | + | + | – |
| 8 | NIS, MISIC, & BKT | + | + | + | – |

*Note:* + denotes presence of SLD; – denotes absence of SLD. NIS = NIMHANS Index for Specific Learning Disability; MISIC = Malin's intelligence scale for Indian children; BKT = Binet-Kamat test of intelligence. Each participant was diagnosed to have SLD based on the results of the psycho-educational battery, contextual assessment, and interviews with participants and their parents.



variant of the congruent as well as the incongruent stimuli were presented 10 times, thus a total of 80 words were presented to each participant. The order of presentation was randomized across the participants to avoid order effect. The inter-stimulus duration was 3500 ms, which provided ample duration for participants to provide verbal responses. Verbal responses that were initiated 3000 ms post-stimulus presentation were excluded from recording. All the verbal responses were recorded using a desktop microphone connected to a computer that was running the "DMDX" software program. "DMDX" is a stimulus presentation and response acquisition software [30]. The participants' responses were stored through the "DMDX" software on the computer's hard drive for the purpose of analysis. The experiment was conducted in a quiet room located within the school that was free from auditory and visual distraction.

### *2.3.2. Semantic task*

In the semantic task, the participants were required to ignore the speaker's gender, and identify the meaning of the word uttered by the speaker through verbal responses. The nature of stimuli presentation and recording of the vocal responses were similar to the gender identification task. Schematic representations of the stimulus presentation in congruent and incongruent conditions for both the tasks are depicted in Figs. 1 and 2, respectively.

### *2.4. Data analysis*

The data was analyzed as a function of performance accuracy and RT. The performance accuracy of the participants was analyzed by perceptually listening to the each of the 80 responses of each participant, and determining if the responses were correct or incorrect. The vocal RT for all the 80 responses produced by each participant was measured by the "DMDX" software.

### *2.5. Statistical analysis*

Two different analyses were carried out. The first analysis compared the performance accuracy of the clinical and control groups on semantic as well as gender identification tasks. The performance accuracy on each task was determined by the percentage of correct responses provided by each participant across the entire 80 words. The performance accuracy scores were subjected to a three-way mixed model ANOVA (2 groups × 2 tasks × 2 conditions). The second analysis compared the performance of the clinical and control groups on the RT task. The RT scores of each participant were subjected to a three-way mixed model ANOVA (2 groups × 2 tasks × 2 conditions). The between-group factor was the group (control and clinical group). The within-group factors were task (semantic and gender identification) and condition (congruent and incongruent). Significant interactions were probed using simple effects analysis with Bonferroni correction for multiple comparisons.

## 3. Results

### *3.1. Performance accuracy*

The three-way mixed-model ANOVA revealed a significant main effect of group, with the control group ($M$ = 98.44, SD = 1.20) performing better than the clinical group ($M$ = 81.09, SD = 1.21), $F$ (1, 14) = 104.28, $p < .001$. There was also a significant main effect for the task, $F$ (1, 14) = 54.01, $p < .001$, as well as for the condition, $F$ (1, 14) = 50.17, $p < .001$. The accuracy of the participants was better on the semantic task ($M$ = 93.67, SD = .67) when compared to gender identification task ($M$ = 85.86, SD = 1.25). The participants performed better on congruent condition ($M$ = 92.66, SD = .79) when compared to incongruent condition ($M$ = 86.88, SD = 1.08). The main effect was qualified by significant interaction of the task × group, $F$ (1, 14) = 38.11, $p < .001$ and condition × group, $F$ (1, 14) = 26.71, $p < .001$.

The post hoc test analyzing the interactive effect of task × group revealed that the control group participants performed better on the semantic task ($M$ = 99.06, SD = .94) compared to gender identification task ($M$ = 97.06, SD = 1.80) ($p < .001$). A similar trend was observed in the clinical group with participants performing better on the semantic task ($M$ = 88.28, SD = .94) than

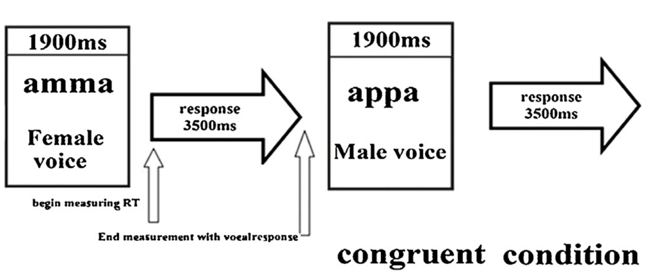


**Fig. 1.** Schematic representation of stimulus presentation during congruent condition for semantic and gender identification tasks.

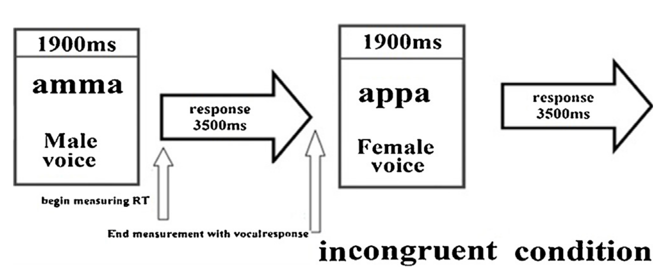


**Fig. 2.** Schematic representation of stimulus presentation during incongruent condition for semantic and gender identification tasks.

on gender identification task ($M = 73.90$, $SD = 1.77$) ($p < .001$). Post hoc test analyzing the interactive effect of condition × group revealed that control group participants had higher accuracy scores on congruent condition ($M = 99.22$, $SD = 1.13$) when compared to incongruent condition ($M = 97.65$, $SD = 1.52$) ($p < .001$). Similarly, participants in the clinical group performed better on congruent condition ($M = 86.09$, $SD = 1.13$) than on incongruent condition ($M = 76.09$, $SD = 1.52$) ($p < .001$).

### 3.2. RT

The three-way mixed-model ANOVA revealed a significant main effect of group, with the control group participants ($M = 639.16$, $SD = 38.41$) performing better on the RT than the clinical group participants ($M = 792.69$, $SD = 38.40$), $F(1, 14) = 7.99$, $p < .01$. There was also a significant main effect for task, $F(1, 14) = 32.42$, $p < .001$ as well as for condition, $F(1, 14) = 16.03$, $p < .001$. The main effect was qualified by a significant three-way interaction of the group, task and condition, $F(1, 14) = 9.80$, $p < .01$. The simple effect analysis revealed that the control group showed a significant decrease in RT for gender identification task in congruent condition ($M = 621.23$, $SD = 36.70$) than in incongruent condition ($M = 710.40$, $SD = 63.63$) ($p < .05$). Similarly, the clinical group showed a significant decrease in RT for gender identification task in congruent condition ($M = 688.50$, $SD = 36.70$) than in incongruent condition ($M = 1024.97$, $SD = 63.63$) ($p < .05$). All the other pairwise comparisons were not significant. The mean RT and percentage accuracy scores for the clinical and control group participants across both semantic and gender identification tasks are presented in Table 2.

## 4. Discussion

The current study compared the auditory interference control of children with LD to a control of group of participants through two versions of an auditory Stroop task. The results suggest that participants with LD took longer time to respond and performed poorly compared to the control group, thus suggesting poorer auditory interference control. The nature of the task also seemed to influence the outcomes. The specific findings are discussed according to the three research questions that were initially posed.

### 4.1. Is there a difference between participants with LD and control group participants in performance accuracy on semantic and gender identification-based auditory Stroop task?

Overall, the results suggest that there is a difference in performance accuracy between the clinical and control groups on semantic as well as gender identification auditory Stroop tasks. To our knowledge, there has been just one study to investigate auditory interference control in children with LD. Kumar et al. used a word meaning/laterality auditory Stroop task to compare auditory interference control in children with LD to typically developing children, and found that children with LD had prolonged RT and decreased performance accuracy [19]. The findings of the current study are in close agreement with Kumar et al.

There is prior evidence to indicate that individuals with LD exhibit deficits in auditory and phonological processing as a result of abnormalities in central neurological processing [31]. Many aspects of our speech include rapid acoustic events such as release burst of articulators during consonant production and formant transitions during a consonant–vowel (CV) syllable production that happen within few ms. King, Warrier, Hayes, and Kraus studied auditory brainstem responses to a click stimulus and a CV syllable (/da/) in children with LD and typically developing children [22]. Results revealed delayed auditory brainstem responses to the CV syllable /da/ in children with LD compared to typically developing children. The researchers hypothesized that children with LD had specific disruption at the level of the brain stem leading to abnormal cortical processing of speech sounds. Other studies have also found brainstem responses to speech syllables in children with LD to be delayed, suggestive of neural asynchrony [32,33]. These response abnormalities were more pronounced in response to rapid syllable onset and CV formant transitions. According to rapid processing hypothesis, deficits in rapid auditory processing affect the ability to process auditory cues that are necessary to discriminate the phonemes of a language [34]. This causes individuals with LD to perceive sounds in a word (or a sentence) in an abnormal manner.

In the current study, each of the stimuli words presented to the participants contained one of the either four CV syllables: /pa/, /ma/, /ka/, or /na/. Problems in perceiving the rapid formant transitions associated with these CV syllables could have resulted in clinical group participants identifying the target words incorrectly. This explains the reduced performance accuracy of the participants with LD compared to the control group participants. Past research has shown that performance on auditory Stroop tasks representing conflict between the dimensions of the stimuli (incongruent) to be poorer than on tasks representing congruence between the stimuli dimensions [18]. It is not surprising that clinical as well control group participants demonstrated superior performance in congruent condition than in incongruent condition.

### 4.2. Is there a difference between participants with LD and control group participants in RT on semantic and gender identification-based auditory Stroop task?

Similar to performance accuracy, participants with LD performed poorly than control group participants manifested by prolonged RT on semantic and gender identification tasks. Again, the results of the current study are in close agreement with the findings of Kumar et al. [19]. Previous literature indicates that children with LD tend to react slowly to tasks requiring selective attention due to deficits in central auditory processing. Richards,

**Table 2**
Mean reaction time (ms) and performance accuracy (%) obtained by control and clinical group participants in congruent and incongruent conditions across semantic and gender identification tasks. Standard deviation (SD) values are indicated in parentheses.

| | | Semantic | | Gender identification | |
|---|---|---|---|---|---|
| | | Control group | Clinical group | Control group | Clinical group |
| Mean reaction time (ms) | Congruent | 612.39 (117.45) | 712.51 (94.62) | 621.23 (116.85) | 688.50 (88.89) |
| | Incongruent | 612.63 (145.05) | 744.81 (89.90) | 710.40 (243.84) | 1024.97 (73.06) |
| Performance accuracy (%) | Congruent | 99.68 (0.88) | 92.81 (5.41) | 98.75 (1.89) | 79.38 (6.09) |
| | Incongruent | 98.43 (1.30) | 83.76 (4.63) | 96.88 (3.72) | 68.44 (10.60) |

Samuels, Turnure, and Ysseldyke found that children with LD exhibited longer RT on behavioral measures (e.g., Flanker task) [35]. The researchers attributed the increased RT to slower pickup of information by the central nervous system. Studies investigating latency of auditory brainstem and cortical responses to speech stimuli obtained prolonged latency of responses in children with LD. This is attributed to the abnormal processing of speech stimuli at the level of brainstem and consequently at the level of cortex, indicating a bottom-up causal relationship between the lower and higher regions of the brain [36,37]. Individuals with LD are known to perform poorly not only on distraction tasks but also on non-distraction tasks due to problems with sustained attention [35]. The abnormal processing of the incoming auditory stimuli at the level of central auditory nervous system can explain the increased RT of participants with LD in the current study.

In short, it can be hypothesized that the abnormal central auditory processing of the incoming auditory stimuli can account for the poorer performance of participants with LD with regard to performance accuracy and RT.

### *4.3. Is there an influence of the nature of the auditory Stroop task on the performance accuracy and RT among both the groups of participants?*

Results from the performance accuracy and RT suggest that participants in control as well as clinical group performed better on the semantic task than on the gender identification task, indicating that the nature of the auditory Stroop task plays an important role in determining the auditory interference control. Miyazaki compared the performance of 45 college-going students in two versions of an auditory Stroop task: pitch naming task and a syllable-shadowing task. The auditory interference control of the participants varied significantly between the two task versions suggesting the importance of nature of auditory Stroop task in determining the auditory interference control [10]. The results of the current study are in close agreement with the findings of Miyazaki.

In the current study, the superior performance of the participants in clinical as well as control groups on semantic task could be due to salience of the stimuli words and differences in stages of processing between semantic and gender identification tasks. Words with increased salience are more compelling to be attended to than the usual words. Each of the stimuli words was associated with a relationship construct (father, mother, sister, and brother). It is possible that the participants found these words to be more salient as they were associated with their everyday life, and found it easier to process these words than identifying the speaker's gender who produced these words. Another reason could be the differences in stages of processing between semantic and gender identification tasks. In order to interpret the speaker's gender, the participants must pick up the auditory-sensory information (i.e. speaker's fundamental frequency), this information must be processed into different acoustic features, and finally these features must be converted into linguistic information to infer and label the speaker' gender. On the other hand, in the semantic task the participants can directly decode the linguistic information to interpret the word meaning, thus resulting in faster processing than the gender identification task [18].

## 5. Limitations

Even though this study presents some interesting results, it is not without limitations. First, the low sample size makes it difficult to generalize the findings of the current study. Second, the participants were recruited based on non-probability convenient sampling procedures. Third, even though none of the control group participants reported difficulties in hearing, the participants hearing acuity was not evaluated through a comprehensive audiological evaluation. Fourth, the participants were assessed at the end of the school day, it is likely that the fatigue of the participants could have affected their attention and involvement in the experiment. Finally, the clinical group participants were heterogeneous with regard to SLD. The ideal would be to recruit a homogenous group of participants. But, an inherent drawback in this line of research is the difficulty to recruit a homogenous group of participants with LD [38].

## 6. Conclusion

In spite of these limitations, the current study revealed some interesting findings. Children with LD exhibit poorer auditory interference control. They are not only unable to suppress irrelevant stimuli, but they are also distracted on auditory tasks that do not involve a distractor task. Children with LD also take longer time to process incoming auditory stimuli in comparison to their normal peers. Finally, the nature of the auditory Stroop task plays an important role in determining the interference control. In the current study, the participants performed much better on the semantic than on the gender identification task. So it is important to interpret the findings of the auditory Stroop task in the context of the nature of the task. Future research should aim to design effective intervention protocols to improve auditory interference control in children with LD and also investigate the possibilities of using auditory Stroop as a biomarker of auditory processing.

## Conflict of interest statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

## Acknowledgment

The authors would like to thank the participants as well as the school authorities for their assistance.

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Please cite this article in press as: R.M. Thomas, et al., Auditory interference control in children with learning disability: An exploratory study, Int. J. Pediatr. Otorhinolaryngol. (2015), http://dx.doi.org/10.1016/j.ijporl.2015.09.017

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